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ICAM

FINAL TECHNICAL REPORT

on

GRAPHICAL PRE-AND POST-PROCESSING
FOR SCIENTIFIC COMPUTING
AN AFOSR - DOD DURIP EQUIPMENT GRANT

AFOSR GRANT F49620-94-1-0457
for the period
30 September 1994 - 29 September 1995

ICAM REPORT 96-02-01

INTERDISCIPLINARY CENTER FOR APPLIED MATHEMATICS

Virginia Tech
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VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

Blacksburg, Virginia 24061-0531

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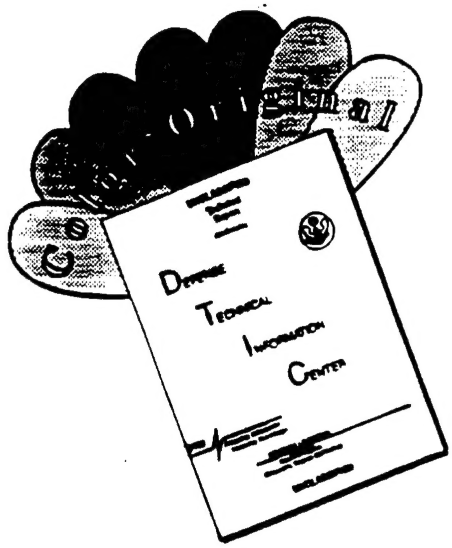

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by

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13. ABSTRACT (Maximum 200 words)

This final technical report contains a summary of the equipment purchased and the research conducted under the AFOSR DURIP Grant F49620-94-J-0457, titled "Graphical Pre-and Post-processing for Scientific Computing", for the period 30 September 1994 to 30 September 1995. During this period, the equipment was used to expand the capabilities of CODAC researchers to develop visualization tools that enhance scientific understanding and facilitate engineering design. Much of the work is concentrated on optimal design and control of systems described by partial differential equations. Therefore, the graphical tools were needed to develop spatial discretizations and associated computational grids. The sensitivity equation method is being applied to various shape optimization and flow tailoring problems. The computational and graphical equipment purchased under this grant is being used to develop an interactive design tools for aerospace systems. The report contains a description of the equipment and a brief summary of some of the on-going research projects that are using this equipment.

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1 Equipment Purchased

The principal equipment purchased under the grant were

1. four SGI Indigo workstations
2. two HP 1600CM color printers

2 Scientific Justification

The equipment purchased under this grant has enhanced our abilities to do fundamental research and has aided in the industrial transition of this work in at least three ways:

1. pre-processing for scientific computations
2. post-processing for scientific visualization
3. development of interactive design tools

2.1 Pre-processing for scientific computations

Much of our work is focused on control and design of systems described by partial differential equations. Accordingly, there is a need for spatial discretization and associated computational grids. Furthermore, the geometrical complexity of three-dimensional objects encountered in realistic scientific computations requires substantial preparation of grids before one can enter into the solution phase of a numerical simulation. For example, in [1], we studied optimization of the shape of a forebody simulator (see, [3],[8]), using a flow solver based on *unstructured* grids [2]. Unstructured grids are important in applications, wherein actual boundaries may be irregular.

The computational geometry for the problem is described by a trapezoidal domain with the forebody removed. A typical grid is shown in 1. The boundary conditions are specified in the following way: 1) inflow conditions are applied on the left side and slanted top portion, 2) a simple first order extrapolation outflow is specified for the right side, 3) tangency is applied on the curved forebody, and 4) a symmetry condition is applied on the horizontal boundary preceding the forebody. Modern engineering workstations, such as the SGI Indigo's obtained under this grant, are essential to the efficient

generation of such grids. The ability to display and manipulate these grids is crucial to the timely solution of such flow optimization problems.

2.2 Post-processing for scientific visualization

Simulation of the response of distributed systems commonly produces two and/or three-dimensional time-dependent data. Scientific visualization is an emerging discipline that provides tools for representing these responses in ways that help the analyst understand and interpret the results. In [9] we study optimal LQG control of a *driven cavity*. In this problem the goal is to compute optimal feedback functional gains and and use the spatial information in these gains to place sensors/actuators for feedback control. It is important to display these functional gains to the analyst so that he can use the visual information to guide the sensor placement, for example. With the feedback controller in hand, one is interested in simulating the response to demonstrate the effectiveness of the control algorithm. In this facet it is useful to generate time varying flows in the cavity, driven by disturbances. The results of these simlation can be animated for presentation on our workstations.

2.3 Development of interactive design tools

Advances in computational arts - analysis, software and hardware - have greatly enhanced the process of analyzing proposed design concepts. Such advances have occured in virtually all engineering disciplines but especially in those related to advanced aerospace systems. While such analysis tools are important, an even bigger payoff awaits the development of advanced tools for design synthesis.

We expect that before formal optimization is adopted as a common tool, it will be useful to produce tools that guide the contemporary designer. For example, in addition to displaying the simulated flow for a current design, one might also provide information about how a specific geometric change will alter the flow. The designer would use this information, along with a notion of his 'goal' to adjust the geometry and simulate a new flow. We have developed numerical procedures for the efficient calculation of certain design *sensitivities* (see, [4], [5], [6]) for high-speed flow problems. In [1] we applied these ideas to a chemically reacting flow problem with five species of air [7], [10] [11]. Shown in 2 is the computed sensitivity for the amount of nitrous

oxide in the flow to the inflow velocity. From such information, the designer can judge the effect of such changes on the flow.

3 Educational Component

The Interdisciplinary Center for Applied Mathematics (**ICAM**) was formed in August 1987 to to promote and facilitate interdisciplinary research and education in applied mathematics at Virginia Polytechnic Institute and State University. The goal of **ICAM** is to enhance the historical links among mathematics, engineering and the sciences. Core participants in **ICAM** are committed to providing interdisciplinary research experience for both graduate and undergraduate students. The equipment purchased under this grant is available for use by qualified students in their research and in their formal studies.

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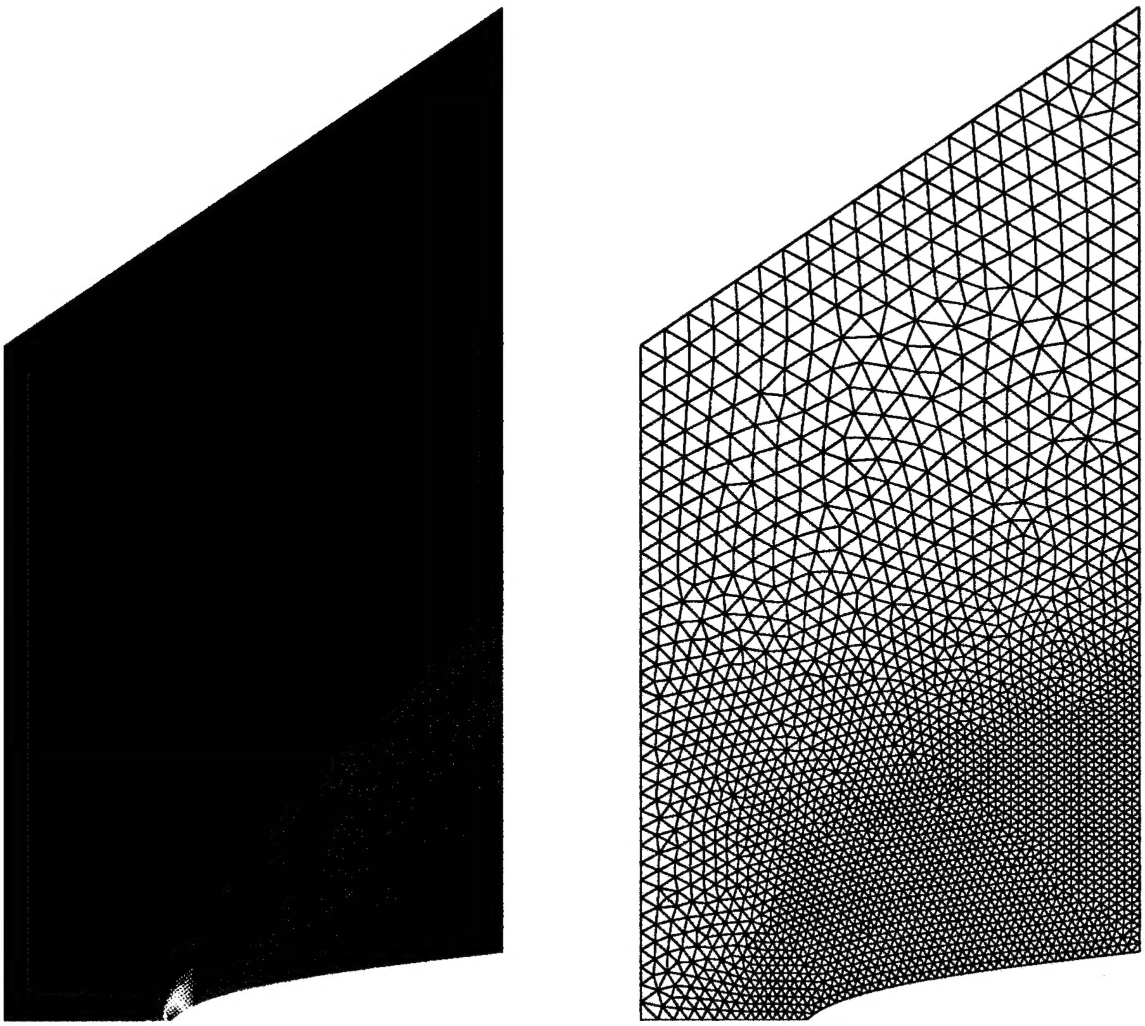

Figure 1: Typical flow and mesh for the forebody simulator on an unstructured mesh.

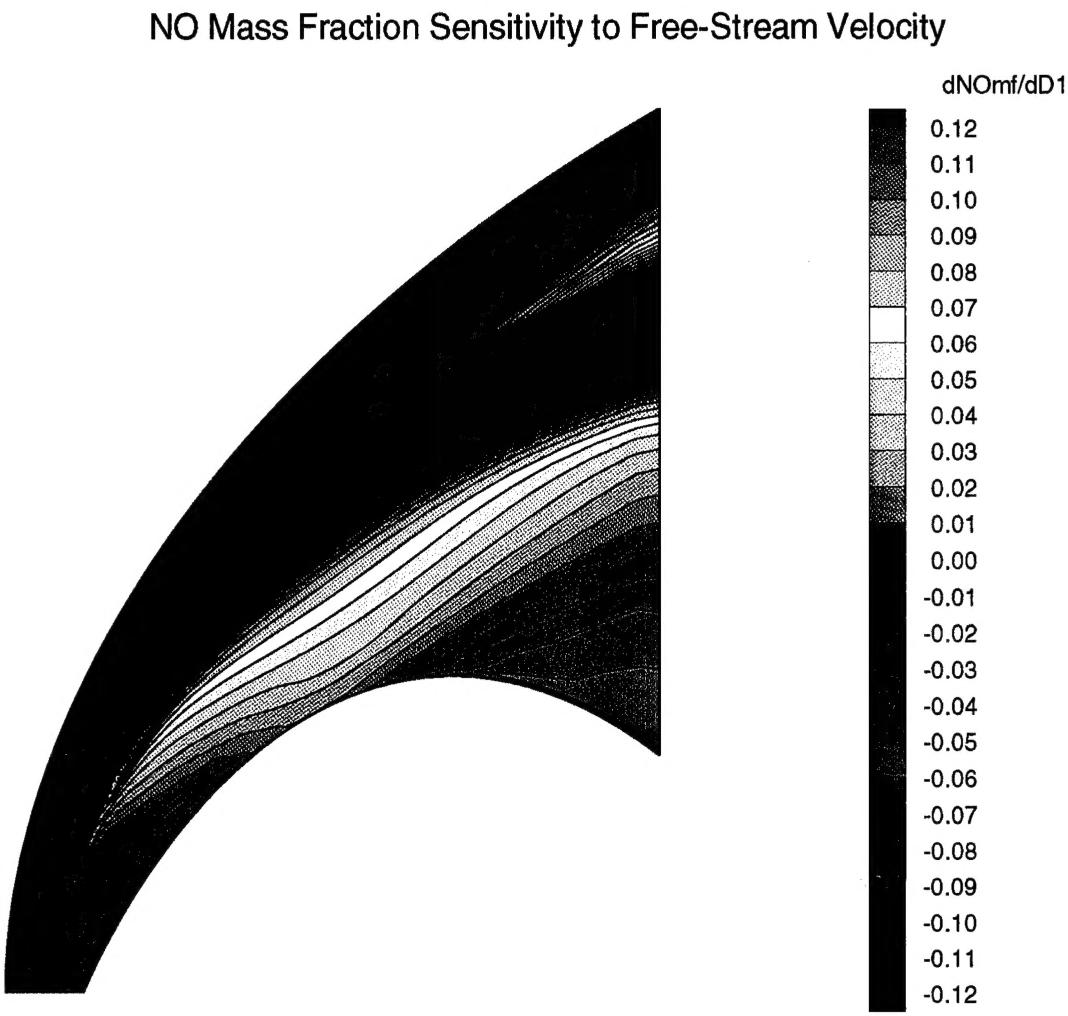

Figure 2: Sensitivity of NO fraction